Claims

We claim:

8. An apparatus for compressing a digital input signal, the apparatus comprising:

index generating means for generating an index in response to the digital input signal;

block length decision means for determining a division of the digital input signal into blocks in response to the index;

block floating processing means for applying block floating processing to the blocks of the digital input signal in response to the index;

orthogonal transform means for orthogonally transforming each block floating processed block of the digital input signal to produce plural spectral coefficients; and

adaptive bit allocation means for dividing the plural spectral coefficients from the orthogonal transform means into bands, and for adaptively allocating a number of quantizing bits to quantize the spectral coefficients in each of the bands.

9. The apparatus of claim 8, wherein:

the digital input signal comprises plural words, each of the plural words having an absolute value; and

the index generating means generates the index by calculating a logical sum of the absolute values of the words.

10. The apparatus of claims 8 or 9, wherein the orthogonal transform means includes a Discrete Cosine Transform circuit.

11. The apparatus of claim 8, wherein:

(a) the index generating means generates an index for each of plural sub blocks obtained by dividing the digital input signal in time;

(b) the block length decision means includes comparing means for comparing the indices of adjacent sub blocks of the digital input signal; and

(c) the block floating processing means applies block floating processing to each block of the digital input signal determined by the block length decision means using a block floating coefficient calculated from the indices of the sub blocks constituting the block.

12. The apparatus of claim 11, wherein:

the digital input signal includes plural words, each word having an absolute value; and

the index calculating means calculates the index for each of the sub blocks by determining a maximum of the absolute values of the words in the sub block.

13. The apparatus of claim 11, wherein:

(a) the index generating means includes:

(1) means for dividing the digital input signal in time into sub blocks, and

(2) index calculating means for calculating an index for each sub block; and

(b) the block length decision means additionally includes block defining means, responsive to the comparing means, for determining a division of the digital input signal in time into blocks composed of a selected one of one sub block, two sub blocks, and four sub blocks.

14. The apparatus of claim 13, wherein:

the means for dividing the digital input signal in time into sub blocks includes:

means for dividing the digital input signal in time into frames, and

means for dividing each frame into a first sub block and a second sub block;

the comparing means is for comparing the indices of the first sub block and the second sub block; and

the block defining means determines a division of each frame of the digital input signal into two equal blocks when the index of the second sub block is twenty or more times the index of the first sub block, and otherwise determines a division of the frame of the digital input signal into a single block.

15. The apparatus of claim 13, wherein:

(a) the means for dividing the digital input signal in time into sub blocks includes:

(1) means for dividing the digital input signal in time into frames, and

(2) means for dividing each frame into a first half sub block, a second half sub block, and into four quarter sub blocks;

(b) the comparing means is for comparing the indices of the first half sub block and the second half sub block and for comparing the indices of pairs of adjacent quarter sub blocks, each pair of adjacent quarter sub blocks including a first quarter sub block and a second quarter sub block; and

(c) the block defining means determines a division of each frame of the digital input signal:

(1) into four equal blocks when the index of the second of any pair of adjacent quarter sub blocks is twenty or more times greater than the index of the first of any pair of adjacent quarter sub blocks,

(2) into two equal blocks when the index of the second half sub block is ten or more times, but less than twenty times, the index of the first half sub block, and

(3) into a single block when the index of the second half sub block less than ten times the index of the first half sub block.

16. The apparatus of claim 8, wherein the adaptive bit allocation means is for dividing the spectral coefficients into bands corresponding to critical bands.

17. The apparatus of claim 8, wherein the adaptive bit allocation means is for dividing the spectral coefficients towards higher frequencies into bands corresponding to a fraction of a critical band.

18. An apparatus for compressing a digital input signal, the apparatus comprising:

means for deriving plural spectral coefficients from the digital input signal; and

adaptive bit allocation means for dividing the spectral coefficients by frequency into bands and for adaptively allocating a number of quantizing bits for quantizing the spectral coefficients in each of the bands in response to an allowed noise level for each of the bands, the adaptive bit allocation means comprising:

allowable noise level calculation means for calculating an allowed noise level for each of the bands;

comparing means for comparing, in each of the bands, the allowable noise level with a minimum audible level; and

selecting means for selecting the minimum audible level as the allowable noise level for each of the bands wherein the comparing means determines that the minimum audible level is higher than the allowable noise level.

19. The apparatus of claim 18, wherein the means for deriving plural spectral coefficients from the digital input signal includes an orthogonal transform circuit.

20. The apparatus of claim 19, wherein the orthogonal transform circuit is a Discrete Cosine Transform (DCT) circuit.

21. The apparatus of claims 18 or 19, wherein:

the adaptive bit allocation means quantizes the spectral coefficients using an actual number of bits;

the apparatus additionally includes:

means for providing an output signal including a target number of bits, and

means for determining an error between the actual number of bits and the target number of bits; and

the allowable noise level calculation means includes means for adjusting the allowable noise level in response to the error between the actual number of bits and the target number of bits.

22. The apparatus of claim 21, wherein the adaptive bit allocation means includes adjusts the number of quantizing bits allocated to the bands in response to changes in the allowable noise level caused by the means for adjusting the allowed noise level.

23. The apparatus of claims 18 or 19, wherein the means for deriving spectral coefficients from the digital input signal includes:

block length decision means for determining a division of the digital input signal in time into blocks in response to an index;

block floating means for applying block floating processing to each block of the digital input signal using the index as a block floating coefficient; and

means for deriving the spectral coefficients from the block floating processed blocks of the digital input signal.

24. The apparatus of claims 18 or 19, wherein:

the adaptive bit allocation means is additionally for dividing the spectral components in a band corresponding to a critical band into plural sub bands, the plural sub bands including a lowest frequency sub band;

the comparing means is for comparing, in the band corresponding to a critical band, the allowable noise level for the band with the minimum audible level for the lowest frequency sub band; and

the selecting means is for selecting, as the allowable noise level for the band corresponding to the critical band, the minimum audible level of the lowest frequency sub band when the comparing means indicates that the minimum audible level of the lowest frequency sub band is higher than the allowable noise level.

1. (amended) An apparatus for compressing a digital input signal, the apparatus comprising:

a band division filter for dividing the digital input signal into a frequency range signal in each of plural frequency ranges;

a block length decision circuit for determining a division of each frequency range signal in time into blocks in response to an index;

a block floating processing means for applying block floating processing to each frequency range signal in response to the index;

orthogonal transform means for orthogonally transforming each block floating processed frequency range signal to produce plural spectral coefficients, the orthogonal transform means transforming each frequency range signal in blocks determined by the block length decision means; and

adaptive bit allocation means for dividing the plural spectral coefficients from the orthogonal transform means into bands and for adaptively allocating a number of quantizing bits to quantize the spectral coefficients in each of the bands in response to an allowable noise level in each of the bands.

2. (amended) The apparatus of claim 1, wherein:

each frequency range signal includes plural words, each of the words having an absolute value; and

the apparatus additionally includes an generating means for generating the index by calculating a logical sum of the absolute values of the words.

25. The apparatus of claims 1 or 2, wherein the orthogonal transform means includes a Discrete Cosine Transform circuit.

26. The apparatus of claim 1, wherein:

(a) the apparatus additionally comprises an index generating means for generating an index for each of plural sub blocks obtained by dividing each frequency range signal in time;

(b) the block length decision means determines a division of each frequency range signal in time into blocks by comparing the indices of adjacent sub blocks of the respective frequency range signal; and

(c) the block floating processing means applies block floating processing to each block of each frequency range signal determined by the block length decision means using a block floating coefficient calculated from the indices of the sub blocks constituting the block.

27. The apparatus of claim 26, wherein

each frequency range signal includes plural word, each word having an absolute value; and

the index calculating means calculates the index for each sub block by determining a maximum absolute value for the sub block.

28. The apparatus of claim 26, wherein:

(a) the index generating means includes:

(1) means for dividing each frequency range signal in time into sub blocks, and

(2) an index calculating means for calculating the index for each sub block;

(b) the block length decision means includes:

(1) a comparing means for comparing the indices of adjacent sub blocks, and

(2) a block defining means, responsive to the comparing means, for determining a division of each frequency range signal into blocks composed of a selected one of one sub block, two sub blocks, and four sub blocks.

29. The apparatus of claim 28, wherein:

the means for dividing each frequency range signal in time into sub blocks is additionally for dividing each frequency range signal into frames, and for dividing each frame into a first sub block and a second sub block;

the comparing means is for comparing the indices of the first sub block and the second sub block; and

the block defining means determines a division of each frame of each frequency range signal into two equal blocks when the index of the second sub block is twenty or more times the index of the first sub block, and otherwise determines a division of the frame into a single block.

30. The apparatus of claim 28, wherein

the means for dividing each frequency range signal in time into sub blocks is additionally for dividing each frequency range signal into frames, and for dividing each frame into a first half sub block, a second half sub block, and four quarter sub blocks;

the comparing means is for comparing the indices of the first half sub block and the second half sub block and for comparing the indices of pairs of adjacent quarter sub blocks, each pair of adjacent quarter sub blocks including a first quarter sub block and a second quarter sub block; and

the block defining means is for determining a division of each frame of each frequency range signal:

into four equal blocks when the index of the second of any pair of adjacent quarter sub blocks is twenty or more times greater than the index of the first of any pair of adjacent quarter sub blocks,

into two equal blocks when the index of the second half sub block is ten or more times, but less than twenty times, the index of the first half sub block, and

into a single block when the index of the second half sub block less than ten times the index of the first half sub block.

3. (amended) An apparatus for compressing a digital input signal, the apparatus comprising:

band division filter means for dividing the digital input signal into a frequency range signal in each of plural frequency ranges;

block floating processing means for applying block floating processing to each frequency range signal divided in time into blocks;

orthogonal transform means for orthogonally transforming each block of each frequency range signal to provide plural spectral coefficients; and

adaptive bit allocation means for dividing the spectral coefficients from the orthogonal transform means into bands and for adaptively allocating a number of quantizing bits for quantizing the spectral coefficients in each of the bands in response to an allowable noise level in each of the bands, the adaptive bit allocation means including:

allowable noise level calculation means for calculating the allowable noise level for each of the bands,

comparison means for comparing, in each of the bands, the allowable noise level with a minimum audible level and for setting a flag for each of the critical bands wherein the minimum audible level is higher than the allowable noise level, and

means for selecting, in each of the bands wherein the flag is set, the minimum audible level as the allowed noise level.

4. (amended) The apparatus of claim 3, wherein:

the adaptive bit allocation means quantizes the spectral coefficients using an actual number of quantizing bits;

the apparatus additionally includes:

means for providing an output signal including a target number of bits, and

means for determining an error between the actual number of bits and the target number of bits; and

the allowable noise level calculation means calculates the allowed noise level from an energy in each of the bands, and includes means for adjusting the allowable noise level in response to the error between the actual number of bits and the target number of bits.

5. (amended) The apparatus of claim 4, wherein the adaptive bit allocation means additionally includes means for adjusting the number of quantizing bits allocated to each of the bands by changing the allowable noise level.

31. The apparatus of claim 3, wherein:

the adaptive bit allocation means is additionally for dividing the spectral components in one critical band from the orthogonal transform means into plural bands, the plural bands including a lowest frequency band; and

the comparison means is for comparing, in the critical band, the allowable noise level for the critical band with the minimum audible level for the lowest frequency band, and for setting the flag for the critical band when the minimum audible level of the lowest frequency band is higher than the allowable noise level.

6. (amended) The apparatus of claim 3, wherein:

the apparatus additionally comprises a block length decision means for determining a division of each frequency range signal in time into blocks in response to an index;

the block floating processing means applies block floating processing to each block of each frequency range signal using the index as a block floating coefficient; and

the orthogonal transform means transforms each block floating processed frequency range signal in blocks determined by the block length decision means.

7. (amended) The apparatus of claims 3, 4, 5, or 6, wherein the orthogonal transform means includes a Discrete Cosine Transform (DCT) circuit.

32. A method for compressing a digital input signal, the method comprising the steps of:

generating an index in response to the digital input signal;

determining a division of the digital input signal into blocks in response to the index;

applying block floating processing to the blocks of the digital input signal in response to the index;

orthogonally transforming each block floating processed block of the digital input signal to produce plural spectral coefficients; and

dividing the plural spectral coefficients into bands, and adaptively allocating numbers of quantizing bits to quantize the spectral coefficients in each of the bands.

33. The method of claim 32, wherein:

the digital input signal comprises plural words, each of the plural words having an absolute value; and

in the step of generating an index, the index is generated by calculating a logical sum of the absolute values of the words.

34. The method of claims 32 or 33, wherein, in the step of orthogonally transforming each block floating processed block of the digital input signal, each block floating processed block of the digital input signal is orthogonally transformed using a discrete cosine transform.

35. The method of claim 32, wherein:

(a) in the step of generating an index, an index is generated for each of plural sub blocks obtained by dividing the digital input signal in time;

(b) the step of determining a division of the digital input signal into blocks includes the step of comparing the indices of adjacent sub blocks of the digital input signal; and

(c) in the step of applying block floating processing to each block of the digital input signal, block floating processing is applied to each block of the digital input signal using a block floating coefficient calculated from the indices of the sub blocks constituting the block.

36. The method of claim 35, wherein:

the digital input signal includes plural words, each word having an absolute value; and

in the step of calculating an index, the index for each of the sub blocks is calculated by determining a maximum of the absolute values of the words in the sub block.

37. The method of claim 35, wherein:

(a) the step of calculating an index includes the steps of:

(1) dividing the digital input signal in time into sub blocks, and

(2) calculating an index for each sub block; and

(b) in the step of determining a division of the digital input signal into blocks, a division of the digital input signal in time into blocks composed of a selected one of one sub block, two sub blocks, and four sub blocks is determined in response to the step of comparing the indices of adjacent sub blocks.

38. The method of claim 37, wherein:

(a) the step of dividing the digital input signal in time into sub blocks includes the steps of:

(1) dividing the digital input signal in time into frames, and

(2) dividing each frame into a first sub block and a second sub block;

(b) in the step of the comparing the indices of adjacent sub blocks, the indices of the first sub block and the second sub block are compared; and

(c) in the step of determining a division of the digital input signal into blocks, a division of each frame of the digital input signal into two equal blocks is determined when the step of comparing determines that the index of the second sub block is twenty or more times the index of the first sub block, and a division of the frame of the digital input signal into a single block is otherwise determined.

39. The method of claim 37, wherein:

(a) the step of dividing the digital input signal in time into sub blocks includes the steps of:

(1) dividing the digital input signal in time into frames, and

(2) dividing each frame into a first half sub block, a second half sub block, and into four quarter sub blocks;

(b) in the step of comparing the indices of adjacent sub blocks, the indices of the first half sub block and the second half sub block are compared, and the indices of pairs of adjacent quarter sub blocks are compared, each pair of adjacent quarter sub blocks including a first quarter sub block and a second quarter sub block; and

(c) in the step of determining a division of the digital input signal in time into blocks, the division of each frame of the digital input signal is determined as follows:

(1) into four equal blocks when the step of comparing indicates that the index of the second of any pair of adjacent quarter sub blocks is twenty or more times greater than the index of the first of any pair of adjacent quarter sub blocks,

(2) into two equal blocks when the step of comparing indicates that the index of the second half sub block is ten or more times, but less than twenty times, the index of the first half sub block, and

(3) into a single block when the step of comparing indicates that the index of the second half sub block less than ten times the index of the first half sub block.

40. The method of claim 32, wherein, in the step of dividing the plural spectral coefficients into bands, the spectral coefficients are divided into bands corresponding to critical bands.

41. The method of claim 32, wherein, in the step of dividing the plural spectral coefficients into bands, the spectral coefficients towards higher frequencies are divided into bands corresponding to a fraction of a critical band.

42. The method of claim 32, wherein:

the method additionally comprises the step of dividing the digital input signal into a frequency range signal in each of plural frequency ranges;

in the step of generating an index in response to the digital input signal, an index is generated in response to each frequency range signal;

in the step of determining a division of the digital input signal into blocks, the division of each frequency range signal into blocks is determined in response to the respective index;

in the step of applying block floating processing to the digital input signal, block floating processing is applied to the blocks of each frequency range signal in response to the respective index; and

in the step of orthogonally transforming each block floating processed block of the digital input signal, each block floating processed block of each frequency range signal is orthogonally transformed to produce the plural spectral coefficients.

43. A method for compressing a digital input signal, the method comprising the steps of:

deriving plural spectral coefficients from the digital input signal;

dividing the spectral coefficients by frequency into bands; and

adaptively allocating a number of quantizing bits for quantizing the spectral coefficients in each of the bands in response to an allowed noise level for each of the bands, the step of adaptively allocating a number of quantizing bits comprising the steps of:

calculating an allowable noise level for each of the bands,

comparing, in each of the bands, the allowable noise level with a minimum audible level, and

selecting the minimum audible level as the allowable noise level for each of the bands wherein the step of comparing determines that the minimum audible level is higher than the allowable noise level.

44. The method of claim 43, wherein the step of deriving plural spectral coefficients from the digital input signal includes the step of orthogonally transforming the digital input signal.

45. The method of claim 44, wherein, in the step of orthogonally transforming the digital input signal, the digital input signal is orthogonally transformed using a discrete cosine transform.

46. The method of claims 43 or 44, wherein the method provides a compressed signal including a target number of bits, and wherein:

in the step of adaptively allocating a number of quantizing bits, the spectral coefficients are quantized using an actual number of bits;

the method additionally includes the step of determining an error between the actual number of bits and the target number of bits; and

the step of adaptively allocating a number of quantizing bits includes the step of adjusting the allowable noise level in response to the error between the actual number of bits and the target number of bits.

47. The method of claim 46, wherein, in the step of adaptively allocating a number of quantizing bits, the number of quantizing bits allocated to the bands is adjusted in response to changes in the allowable noise level caused by the step of adjusting the allowed noise level.

48. The method of claims 43 or 44, wherein the step of deriving spectral coefficients from the digital input signal includes the steps of:

determining a division of the digital input signal in time into blocks in response to an index;

applying block floating processing to each block of the digital input signal using the index as a block floating coefficient; and

deriving the spectral coefficients from the block floating processed blocks of the digital input signal.

49. The method of claims 43 or 44, wherein:

in the step dividing the spectral coefficients into bands, the spectral components are divided into bands including a band corresponding to a critical band, and the spectral coefficients in the band corresponding to a critical band are divided into plural sub bands, the plural sub bands including a lowest frequency sub band;

in the step of comparing the allowable noise level for the band corresponding to a critical band is compared with the minimum audible level for the lowest frequency sub band; and

in the step of selecting, the minimum audible level for the lowest frequency sub band is selected as the allowable noise level for the band corresponding to the critical band when the step of comparing indicates that the minimum audible level of the lowest frequency sub band is higher than the allowable noise level.

50. The method of claim 43, wherein the step of deriving plural spectral coefficients from the digital input signal comprises the steps of:

dividing the digital input signal into a frequency range signal in each of plural frequency ranges;

generating an index in response to each frequency range signal;

determining a division of each frequency range signal into blocks in response to the respective index;

applying block floating processing to the blocks of each frequency range signal in response to the respective index; and

orthogonally transforming each block floating processed block of each frequency range signal to produce the plural spectral coefficients.

51. An apparatus for expanding a compressed digital signal including plural quantized spectral coefficients and auxiliary information, the apparatus comprising:

adaptive bit allocation decoding means, operating in response to the auxiliary information, for inversely quantizing the quantized spectral coefficients to provide plural spectral coefficients;

block floating means for applying block floating to the spectral coefficients;

inverse orthogonal transform means for inversely orthogonally transforming the block floating processed spectral coefficients to provide plural frequency range signals; and

inverse filter means for synthesizing the frequency range signals to provide an output signal.

52. The apparatus of claim 51, wherein the inverse orthogonal transform means includes an inverse discrete cosine transform circuit.

53. The apparatus of claim 51, wherein:

(a) the apparatus is for expanding a compressed digital signal wherein:

(1) the spectral coefficients are quantized in critical bands,

(2) at least one higher frequency critical band is divided into plural sub bands, the sub bands including a lowest frequency sub band, and

(3) the auxiliary information includes an allowable noise level for each critical band, the allowable noise level for the critical band divided into sub bands being the allowable noise level for the lowest frequency sub band; and

(b) the apparatus additionally comprises means for determining an allowable noise level for each sub band in the critical band in response to the allowable noise level for the critical band.

54. A method for expanding a compressed digital signal to provide a digital output signal, the compressed digital signal including plural quantized spectral coefficients divided by frequency into bands, at least one of the bands being a divided band wherein the spectral coefficients in the band are further divided by frequency into sub bands, the compressed digital signal additionally including an allowed noise level for each band, and, for each divided band, a flag signal, the quantized spectral coefficients in each band and sub band being quantized using an adaptively-allocated number of quantizing bits, the method comprising the steps of:

setting, in each divided band, the allowed noise level of the band as the allowed noise level for the band when the flag signal for the band is in a first state, and setting, in each divided band, the allowed noise level of the band as the allowed noise level for one of the sub bands constituting the band when the flag signal for the band is in a second state;

determining, in each divided band, from the allowed noise level of the band, an allowed noise level for each of other sub bands constituting the band;

using the allowable noise level for each band and sub band to inversely quantize the respective quantized spectral coefficients in each band and sub band to provide spectral coefficients; and

deriving the digital output signal from the spectral coefficients.

55. The method of claim 54, wherein:

the allowed noise level for each divided band is the allowed noise level for the lowest-frequency sub band in the divided band; and

in the step of determining an allowed noise level for each of other sub bands, the allowed noise level for each of the other sub bands higher in frequency than the lowest-frequency sub band is calculated.

56. The method of claim 54, wherein:

the method additionally includes the step of providing a read-only memory wherein allowable noise levels are stored; and

the step of determining an allowed noise level for each of other sub bands constituting the band includes the step of reading an allowed noise level for each of the other sub bands from the read-only memory in response to the allowed noise level for the band.

57. The method of claim 54, wherein the step of deriving the digital output signal from the spectral coefficients includes the steps of:

dividing the spectral coefficients by frequency into plural frequency ranges;

inversely orthogonally transforming the spectral coefficients in each frequency range to provide a frequency range signal; and

synthesizing the frequency range signals to provide the digital output signal.

58. The method of claim 54, wherein in the compressed digital signal, the plural quantized spectral coefficients are divided by frequency into bands corresponding to critical bands.

//